A Study of Simulation Effectiveness in Modeling Heavy Combined Arms Combat in Urban Environments

A Monograph

by

Major Carl Rodger Jacquet

United States Army

School of Advanced Military Studies

United States Army Command and General Staff College

Fort Leavenworth, Kansas

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______________________________ Timothy M. Challans, Ph.D.	Monograph Director
______________________________ Kevin C.M. Benson, COL, AR	Director, School of Advanced Military Studies
______________________________ Robert F. Baumann, Ph.D.	Director, Graduate Degree Programs

Abstract

A Study of Simulation Effectiveness in Modeling Heavy Combined Arms Combat in Urban Environments by Major Carl R. Jacquet, USA, 66 pages.

During the Cold War, combined arms heavy force tactics dictated that forces should avoid urban areas when possible. However, since the beginning of Operation Iraqi Freedom, heavy forces have fought in every urban area in Iraq. The United States Army has clearly rediscovered combined arms heavy force tactics, but there currently exists no validated and effective live, virtual, or constructive training simulation to adequately prepare U.S. Army forces to deal with insurgents in urban terrain. This study examined selected simulations currently in use for training and analysis, compared them against urban warfare requirements derived from key historical battles, and recommended requirements for future simulations that will better prepare the nation's soldiers for the urban battlefield of today and tomorrow.

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INTRODUCTION

The commander had ordered "REDCON-1" over the company net. The lieutenant started his short-count, and soon, all four M1 tanks achieved idle speed on their turbine engines and prepared to move out. As the candy-scented diesel exhaust peculiar to the Abrams tank wafted into his nose, the lieutenant remembered the words of his Armor Officer Basic Course instructor at Fort Knox, Kentucky, eight months earlier, "Lieutenant, only a fool enters an urban area—Bypass, bypass, bypass.[1]" The Assassins of Team A, 2nd Battalion, 70th Armor had cleared the highway of Iraqi resistance, and pushed the surviving irregulars into the city proper. The tanks and Bradley Fighting Vehicles of the company-team had advanced as far as the highway ditch, and were using their thermal sights to scan the first block of houses—Negative Contact. The forward divisions needed their supply convoys to use the highway unmolested by enemy action, and the town overlooked the highway. The Assassins had to clear the town. In violation of every rule-of-thumb created by mechanized forces since WWI,[2] Team A commenced their attack.[3]

The above vignette typifies the experience of United States armored forces in Operation Iraqi Freedom. Since the inception of tanks and armored vehicles into the U.S. Army during World War I, armored doctrine has stated that forces should avoid urban areas. Although the troops easily avoided urban areas on the no-man's land of the 1918 battlefield, future wars would make that much more difficult. Avoiding urban areas allowed tankers to use the advantage of the vehicle's longer weapons range compared to most infantry weapons. Open area also allowed them to avoid the danger of enemy infantry closing to within the dead spots of the vehicles' sights

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[1]Headquarters Department of the Army, *Tank platoon, FM 17-15* (Washington, D.C.: Government Printing Office, 1987), 51.

[2]The old FM 17-15 (Tank Platoon) described bypassing urban areas. The new manual, FM 3-20.15 (dtd. 22 February 2007), incorporates a new, very detailed, urban combat chapter.

[3]Headquarters Department of the Army, *Field manual 3-20.15 tank platoon* (Washington, D.C.: Government Printing Office, 2007), 221.

and weapons. Instructors at the U.S. Armor School had transformed the avoidance of urban areas into a quasi-religious mantra in the 1980's, a rule that the "tankers" would not violate until 2003.

As much as the instructors at the Armor School would like to believe the universality of their mantra, the actual history of the United States Army illustrates a much different past. The use of combined arms forces in urban areas dates back to World War II, where many European towns and cities required the use of both armor and infantry to clear the myriad buildings.[4] In fact, combined arms attacks on urban areas became a common occurrence in U.S. military history almost to the end of the Vietnam War, particularly in the city of Hue in 1968[5]. The focus and competency of the U.S. military in urban warfare disappeared after Vietnam, however. Defending Europe from the "Russian Horde" changed the Army, and allowed it to forget urban combat, with the exception of Berlin[6]. The NATO peculiarity of relying on host nation forces to conduct urban operations within their own borders (with the exception of the Berlin units, which consisted of mostly light infantry) allowed the U.S. Army to regard the urban battle as non-essential, and ignore the importance of training for combined-arms urban warfare. Germany-based American units largely did not worry about conducting urban operations around the small towns in the Fulda Gap. They placed their faith that the locals would side with NATO, and that the fight in those towns belonged to the Germans. While America relied on others to handle urban fights, the doctrine for doing so disappeared from Army manuals.

Historical examples exist, and Army and academic historians have performed sufficient case studies that the urban warfare manuals could have existed, had the U.S. Army decided to publish them. Unfortunately, the infantry school had not updated the manual on urban warfare,

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[4]Kendall D. Gott, *Breaking the mold : Tanks in the cities.* (Fort Leavenworth, KS: Combat Studies Institute Press, 2006), 9.

[5]Gott 2006, 23.

[6]Edward McHale, Personal communication with COL Edward McHale, former member of Berlin brigade, FRG, during the Cold War. (Unpublished Personal Discussion, 2007).

FM 90-10[7], since 1979, and the infantry school at Fort Benning published FM 3-06.11, Combined Arms Urban Operations in Urban Terrain in 2002, which succeeded its 1993 predecessor FM 90-10-1, An Infantryman's Guide to Combat in Built-up Areas.

During the height of the Cold War in Europe, the U.S. Army's lack of emphasis on urban operations affected more than just its doctrine. All supporting training manuals, equipment, and training systems that would have been required, requested, procured, and fielded, were never created. Furthermore, the Army's Combat Training Centers did not possess current urban warfare sites until after 1993. Mogadishu's urban sprawl and the two downed Blackhawk helicopters awakened the Army to its lack of urban warfare emphasis, and started its journey to rediscovery of urban tactics.[8]

In addition to the decline of urban tactics in the 1980's and early 1990's, the Army procured fewer devices to train urban operations. Those that did arrive during that time had limitations in urban settings. MILES (Multiple Integrated Laser Engagement System), the ubiquitous training aid, cannot penetrate walls, or even bushes. The revolutionary system that helped reinvigorate training in the 80's also created some negative effects. Soldiers could "survive" by hiding behind "MILES cover"—Anything that blocked the laser signal. Although observers can help negate this factor through adjudication, they cannot adjudicate what they do not see, and there are rarely enough observers.

In addition to the live simulation systems like MILES, the constructive and virtual simulations typically used to progress training from the crawl & walk stage likewise never existed with the required urban capabilities and fidelity that units need to adequately replicate the actual urban battle. After Mogadishu in 1993, and the subsequent dedication of the CTC MOUT sites, many training simulations had to be had to be quickly adapted or "patched," at a great cost

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[7]Russell W. Glenn, National Defense Research Institute and Arroyo Center, *Heavy matter: Urban operations' density of challenges* (Santa Monica, CA: Rand, 2000), 48.
[8]Ralph Peters, *Our Soldiers, Their Cities* (Carlisle Barracks, PA U.S. Army, 1996), 43.

because the developer had not optimized the system to model the complex urban environment. Based on historical precedence and experience, one can assume that friendly and enemy forces will re-use tactics and techniques used in past urban battles. If combat developers view those techniques and tactics as requirements for urban warfare simulations, no simulations would meet every requirement. Additionally, some urban warfare requirements would and do exceed the capabilities of all existing simulations.

Still today in 2007, in an era of unprecedented computing power, no simulation models adequately depict the combined arms urban environment.[9] The common misconception in the training arena is that the models depict the "next best thing" to combat, but the reality stands in stark contrast to the environment created by 1970's technology like MILES and JANUS, which are still in use at most local training areas and installation simulation centers. When using these simulations, heavy combined arms forces cannot blast their way through doors and walls like they do in combat (the wall blocks the laser and it would damage the expensive buildings). Even live-fire exercises have faults. Plywood does not shoot back like the enemy, and does not require the friendly forces to maneuver in a more protective manner. As a result, forces train as they fight, relying on the first few hours of combat to become "blooded" and adapted to warfare's true environment.[10] *The simulations in use today by the U.S. Army do not adequately model the combined arms urban environment.*

If the simulations used by the Army do not sufficiently represent the realities of urban warfare, how can the Army improve them? History has recorded the urban warfare experience of the U.S. Army in the minds of its veterans, and in the pages of history books and official records. Anyone searching for this experience may simply open "the book" to find it. Interestingly, most

[9]Phillip N. Jones and Thomas Mastaglio, *Evaluating the Contributions of Virtual Simulations to Combat Effectiveness* (Arlington, VA: U.S. Army Research Institute for the Behavioral and Social Sciences, 2006), 22.
[10]William S. Wallace, LTG William S. Wallace speech to faculty. (Unpublished Speech: West Point, NY, 2004).

Army organizations do not use historical accounts to build requirements for training devices. They typically use Subject Matter Expert surveys or training exercises to validate their proposed list. Unfortunately, the wording of survey questions can easily bias results. In many cases, SMEs simply answered "yes" or "no" to the question of model sufficiency.[11] Additionally, very few SMEs are truly experts of broad fields like urban warfare and its different requirements. Worse yet, when organizations use training exercises to create requirements for training devices, the likelihood that the model will adequately represent reality approaches zero. This may seem absurd, yet the Army has conducted many modern unit validation and Mission Rehearsal Exercises with unclassified, deliberately faulty, live simulations—Mostly MILES-based. Even when using classified, verified, and validated data, virtually all simulations fail in some regard, particularly when representing urban warfare--The realm of combat the U.S. Army repeatedly neglects.

The following chapters will explore combined arms urban combat from the introduction of armor on the battlefield in World War I, to the recent experiences in the Middle East. The study will use enemy and friendly tactics and techniques found in historical cases to recommend new urban warfare requirements for training simulations in order to increase the effectiveness of urban combined arms combat training and rehearsal exercises.

[11]W. M. Christenson, Mary C. Flythe, Terri J. Walsh, and Robert A. Zirkle, *JCATS Verification and Validation Report* (Fort Belvoir, VA: Defense Technical Information Center, 2002), 63.

CHAPTER TWO

HISTORICAL EXAMPLES OF URBAN WARFARE

Given that *the simulations in use today by the U.S. Army do not adequately model the combined arms urban environment*, and that historians have detailed studies of seminal urban battles, one can use those studies to aid in determining future simulation requirements. Studying historical accounts of battles allows for the inclusion of real historical factors, which may not be included when conducting SME surveys. Additionally, the studies of significant battles have complete data, whereas SMEs must rely on their memories of events, in which they may have experienced only a fraction of the total battle necessary to gain an overall understanding of the tactics in use. Additionally, SMEs with primarily training experience may have a great breadth of knowledge about urban tactics, but they frequently fail to realize that the inadequacies of their training environment have biased their experiences. For example, a soldier who trains repeatedly at a MOUT site has probably never destroyed or modified a structure in order to breach a wall or create a firing port. In order to maintain the facility for future use, they had to restrict the actions of the training units. Unfortunately, destruction and modification of structures typify combined arms urban combat.

The following historical studies of combined arms urban combat illustrate the unique challenges of fighting in such a dynamic and complex environment as the urban landscape. The relevant characteristics of each the battles detail the requirements for modeling such environments, and form the basis for further recommended urban simulation requirements in chapter 4.

WWI

By 1918, the terrain of the European battlefield resembled the surface of the moon. Almost all urban areas had been immolated by artillery and mine warfare. Early tankers worried more about ditches, wire obstacles, and miring their tank in the mud than they did about

negotiating and clearing urban areas. They simply bypassed what few urban areas there were. Because of the lack of urban terrain present on the WWI battlefield, the accounts of combined arms battles in urban areas during that conflict are sparse, if not non-existent. Tankers of that era focused on support of the advancing infantry, and reduction of obstacles that stood in the way of crossing the no-man's land between the trench-lines of the opposing sides.[12]

Aachen:

By the final years of WWII, the Allied combined arms teams had learned the lessons of the Africa and Sicily campaign, and had polished their skills in Operation Cobra, the breakout from Normandy. However, the Allied forces had not practiced urban combined arms operations, though they had trained on operations with infantry-armor teams with one tank supporting an infantry platoon,[13] and had used this technique successfully to escape the Bocage.[14] As the forces approached the Rhine and the West Wall, the increasing concentrations of German defenders obliged them to utilize their tanks in close support once again in order to reduce hardened positions and counter the German's crew-served weapons and armored counter-attacks.[15]

In addition to the moderately successful M4 tanks and meagerly armored M10 tank destroyers, the Americans used 155mm SP artillery in close support direct-fire roles to destroy bunkers and walls that the tank cannons could not penetrate.[16]

The infantry and tanks in the ad-hoc combined arms teams learned quickly to cover each other's move by positioning the infantry to the front flanks of the tank while it rolled down the streets. The tank destroyed enemy positions and heavy weapons, while the accompanying infantry protected it from *Panzerfausts*. This symbiotic relationship allowed the infantry to

[12]Gott 2006, 10.
[13]Gott 2006, 12.
[14]Gott 2006, 6.
[15]Gott 2006, 12.
[16]Gott 2006, 13.

access structures relatively unmolested, and enabled them to perform building clearing by entering through holes made by the tank's main guns, and sometimes by the tank itself.[17] Although the combined arms tactics used at Aachen did not extend above platoon level, they were an overmatch for the Germans due to the use of overwhelming firepower and close coordination with supporting arms of artillery (indirect) and aviation, both bombers and fighters.

Manila

As Stalingrad dictated the style of urban warfare in the Second World War's European Theater, so the battle of Manila set the style of urban warfare in the Pacific Theater. Upon MacArthur's return to the occupied archipelago in January of 1945, the combatants set the stage for the battle for Manila. Unlike in 1942, the warring parties would not declare Manila an open city.[18]

Manila marks a departure from other urban battles due to the number of prepared Japanese fortifications on the Genko Line.[19] Additionally, due to the Japanese tactic of setting fires and laying large demolition charges to delay the allied advance, much of the city burned and created a great amount of smoke obscuration during the ensuing battle.

As much casualties as the American forces took during the liberation of Manila, they stood in stark contrast to those of the defending Japanese, largely because the American forces relied on artillery, mortar, and tank fire to kill their opponents.[20]

Much like Baghdad, rivers and bridges dissect and connect Manila. The amphibious and forced river crossings made by allied forces during the battle decided the fate of the city. As difficult as it may be to model, an attempt should be made to allow for the representation of

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[17]Gott, 2006, 13.
[18]R. M. Connaughton, John Pimlott, and Duncan Anderson, *The battle for Manila.* (Novato, CA: Presidio, 1995), 83.
[19]Connaughton, Pimlott and Anderson 1995, 88.
[20]Connaughton, Pimlott and Anderson 1995, 104.

bridge destruction and laying, as well as river crossing operations and the effects of banks and water on mobility.

Like many old port cities, Manila possessed a walled city, the Intramuros. The allied plan to capture the district involved a great amount of 8-inch and 155mm artillery rounds, fired indirectly and directly at the walls to create a breach. The 20-foot high walls of the moated district measured 40-feet thick at the base, and as much as 20-feet thick at the top. Additionally, much of the walled fortress had been hollowed out and enhanced with firing ports to allow for lateral movement and increased protection for heavy weapons.[21]

The great take-aways from studying the battle for Manila remain the gross amount of artillery and tank fire used by the allied forces to reduce Japanese strongpoints. Additionally, the Japanese frequently defended buildings from the upper floors by firing through or dropping grenades through the floors of the structure.[22] To think that the battle of Manila would be an isolated incident in history would not outlast the next 25 years. The U.S. Army would again fight in a stone-walled city in the former French colony of Indochina.

Vietnam

Soon after the end of the Tet Offensive in 1968, Hue became the quintessential urban battle of the 1960's, and a stark reminder of the need for, and effectiveness of armor in urban operations. As many of the successful urban operations since and during WWII, it involved the use of heavy armor and combined arms. When the NVA and Vietcong captured Hue and posted the Vietcong flag atop the citadel in the opening hours of the battle on 31 January 1968[23], they captured or isolated several allied and U.S. commands, particularly, the MAC-V compound located to the southeast of the citadel, across the Perfume River. In response, the U.S. and ARVN

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[21]Connaughton, Pimlott and Anderson 1995, 161.
[22]Connaughton, Pimlott and Anderson 1995, 157.
[23]George W. Smith, *The siege at hue* (Boulder, Colorado: Lynne Rienner, 1999), 11.

commanders immediately dispatched soldiers and marines to break through to the beleaguered forces, and to destroy the enemy forces that had placed the Vietcong flag over the ancient city.[24]

Upon arrival, the marines and the reinforcing ARVN troops made contact with the enemy. The enemy destroyed many of the ARVN M41 Walker Bulldog tanks with B-40 RPGs and other anti-tank weapons, while one of the five Marine M48A3 tanks suffered a mobility kill from a B-40 rocket. In the ensuing hours, the Marines repaired the M48 tank and replaced injured crewmembers with infantry. The new ad-hoc crews then made their way to the MAC-V compound, blasting resistance the met along the way, and finally reopening access to the personnel trapped inside. The NVA and Vietcong forces did not bring armored forces into the city (they would not repeat this mistake in 1975). They would instead rely on their reliable and mobile B-40 RPGs to destroy enemy armor and fighting positions. Though effective when massed from short distances, the RPGs lacked the range and protection provided by the American M48 and M41 tanks. Additionally, the tanks and M50 Ontos armored vehicles greatly outranged any B-40 gunner. However, the NVA and VC quickly found out that using the B-40 in a near urban ambush greatly improved their odds of destroying the target vehicle, if they survived the close encounter with U.S. and ARVN armor. To counter this effective tactic, the American and ARVN troops used their asymmetric advantage of protection and range to destroy enemy strongpoints and kill from a distance. Judging by the nearly four-to-one difference in casualties from the NVA and VC to the U.S. and ARVN forces, the advantage paid off.[25]

Because the U.S. forces had not practiced urban combat in decades, they initially faltered in the tight confines of the stone maze that is Hue[26]. However, given their high state of training in close-in jungle warfare, they quickly and successfully made the transition to fighting in the

[24]Smith 1999, 12.

[25]Gott 2006, 41.

[26]Nicholas Warr, *Phase line green: The battle for Hue, 1968* (Annapolis, Md.: Naval Institute Press, 1997), 96.

streets. Their lives depended on it. The U.S. Marines learned to use their M48 and M50 Ontos vehicles in close-support of infantry units, eventually placing vehicles down to the infantry platoon level to increase responsiveness to the infantry.[27]

The Marines also adapted to the enemy practice of fortifying the base level of buildings by clearing buildings from the top level down, and they took advantage of the enemy shortage of gas masks by utilizing concentrated CS (tear) gas to weaken enemy resistance.[28]

Not without their own ability to learn from experience, the NVA quickly adapted to the combined arms onslaught by digging trenches and spider holes, blocking the roads, and conducting aggressive counterattacks when the Marines overran positions.[29]

While armor crewman casualties ran high due to the heavy RPG fire and close quarters (not to mention the fact that M50 Ontos crewmen had to reload while exposed) the Marines and ARVN speedily replaced downed armor and tank crewmen with infantry in order to keep the vehicles in action. In addition, the tankers performed hasty repairs to their equipment in combat in order to remain in the fight. As a result, most of the original tanks to enter Hue still operated at the end of the battle--a testament to the resiliency of the equipment and to the determination of the maintenance crews.[30]

Although the Marine and ARVN tactics for using armor with infantry in urban operations emerged haphazardly with Hue in Vietnam, they rapidly refined them as the battle progressed. However, even with the significant firepower and range advantages of the Marines and ARVN

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[27]Although the practice of cross-attaching armor units smaller than platoon violates accepted doctrine, the Marines practiced it frequently, and continue to do so to this day. The rationale for not splitting a unit beyond platoon has to do with the limitations of a section or individual tank to both command and control and report actions and contacts to the higher headquarters (only leader tanks have multiple long-range radios) and in creating a 360 degree security perimeter in the absence of covering infantry. Four vehicles can create a coil and maintain 360 degree scanning patterns on the move. The Marines believe the sacrifice of vehicle security is worth the gain in direct fire support to the infantry.

[28]Gott 2006, 35.

[29]Gott 2006, 37.

[30]Smith 1999, 99.

over their northern counterparts, they still took heavy casualties in the mostly daylight fighting within Vietnam's ancient capital. Allied units lost over 600 dead and 3,600 wounded, while NVA and Vietcong forces lost at least 2,000 to 5,000 dead. Of the allied numbers, the U.S. lost 142 dead in the four weeks of intense fighting among the 8 U.S. battalions involved in the battle[31].

Clearly one of the biggest tactical learning points from the battle of Hue was the NVA and VC fortification of buildings and use of "spider holes" in heavy-walled buildings within the citadel. Although the Marines eventually adapted to the enemy tactic, the initial losses of troops and vehicles almost destroyed many of the units in the 5th Marines.[32] Ironically, this key urban tactical ability of spider holing firing ports in heavy walls cannot be found in modern urban simulations.

Lebanon

The Israeli incursion into Lebanon in 1982 marked a rapid departure from the open desert armored column fights of the 1973 Arab-Israeli War. In seeking to destroy the Palestine Liberation Organization (PLO) and eliminate Syrian capability to counter their moves, the Israeli Defense Force (IDF) seized key PLO stronghold towns in Lebanon, specifically Tyre, Sidon, and Damur.[33] In what may have been a traditional infantry-centric fight, the IDF took armor-heavy columns into towns and dense urban areas. As a result, they encountered irregular resistance from the PLO in the form of terror attacks and urban ambushes. Since the PLO was a "state

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[31] John M. Taylor, *Hue: A 1989 analysis* [Internet on-line]. (Alexandria, VA: Global Security.org, 1989, accessed December 27, 2006); available from http://www.globalsecurity.org/military/library/report/1989/TJM.htm; Internet.

[32] Smith 1999, 195.

[33] Michael C. Desch and Army War College Strategic Studies Institute, *Soldiers in cities: Military operations on urban terrain.* (Carlisle Barracks, PA: Strategic Studies Institute, U.S. Army War College, 2001), 37.

within a state,"[34] destruction of the Lebanese infrastructure did not directly affect the PLO, which had much of its base of support spread around the refugee camps and naturalized Palestinian population. Additionally, the Syrian presence aided the PLO in diverting IDF firepower away from their smaller troop concentrations and forces.

Reeling from the high personnel losses of 1967 and 1973, Israel sought to minimize its troop casualties. However, the urban irregular fight that ensued required the IDF to change its training and tactical focus to heavy combined-arms operations utilizing speed, firepower, and precision to breach urban defenses and reduce friendly casualties. Unfortunately, the successful tactics appear very heavy-handed from an outside viewpoint, and contributed to the eventual pullout of Israel in 2000. A memorable video clip of the fighting in Beirut will always be self-propelled howitzers firing direct-fire into Beirut from the surrounding hillsides.

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[34]Desch and Army War College 2001, 40.

Palestine

Figure 1 Nakpadon APC[35]

The IDF used much of their new tactics from Lebanon in the occupied territories of the West Bank and the Gaza Strip. Due to the losses incurred by the IDF mechanized infantry riding in M113 light APCs, the IDF developed heavy APCs to counter the threats that destroyed the lighter Israeli APCs. The IDF began to use its heavy APCs together with its tanks to perform ballistic breaches into walled compounds using tank guns and demolition charges in order to insert troops into PLO buildings.

Key requirements to modeling IDF urban tactics are full tank ammunition load-outs to include new Multi-Purpose Anti-Tank (MPAT) and canister round terminal ballistics against various walls, and dynamic building surfaces to allow for ballistic breaches of walls and roofs.

In addition, the model must be able to represent the different standoff and command detonated mines, as well as personnel and vehicle-borne explosive devices. Due to the current

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[35]Defense Update, *IDF vehicle protection program* [Internet on-line]. (Defense-Update.com, December 24, 2004, accessed on January 25, 2007); available from http://www.defense-update.com/events/2004/summary/LIC-04-protection.htm; Internet.

proliferation of these devices in combat, future simulations must include them in their in their modeling requirements.

CHAPTER THREE

SIMULATION OVERVIEWS

The simulation models chosen for this study differ greatly in purpose and approach to solving the problem of recreating the combined arms urban fight, *which current simulation models do not adequately represent*. While TAC-OPS takes the minimalist approach, focusing on the decision-making of the leaders, high-fidelity simulations like Steel Beasts 2™ attempt to recreate as much of the environment as possible. Although sometimes contrary to the advertising campaigns of many defense contractors, all models fail in some manner to replicate reality. The question that all trainers must answer is "What features does he or she need to conduct proper training?" Thus, rather than seek a simulation that meets all needed requirements, trainers should adopt a partial-task training methodology which utilizes several simulations and training devices, and focuses each training session on the tasks which each simulation or training aid is best suited for.

This study shall describe simulations using the accepted U.S. Department of Defense terms for Live, Virtual, and Constructive simulations.[36] The following paragraphs describe each simulation chosen for the study, and detail some of their overall strengths and weaknesses.

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[36]Defense Modeling and Simulation Office, *Modeling and Simulation Master Plan.* (Washington, D.C.: Department of Defense, 1995), 68.

Live, Virtual, and Constructive Simulation
A broadly used taxonomy for classifying simulation types. The categorization of simulation into live, virtual, and constructive is problematic, because there is no clear division between these categories. The degree of human participation in the simulation is infinitely variable, as is the degree of equipment realism. This categorization of simulations also suffers by excluding a category for simulated people working real equipment (e.g., smart vehicles). Live Simulation: A simulation involving real people operating real systems. Virtual Simulation: A simulation involving real people operating simulated systems. Virtual simulations inject human-in-the-loop in a central role by exercising motor control skills (e.g., flying an airplane), decision skills (e.g., committing fire control resources to action), or communication skills (e.g., as members of a C4I team). Constructive Model or Simulation: Models and simulations that involve simulated people operating simulated systems. Real people stimulate (make inputs) to such simulations, but are not involved in determining the outcomes

Chapter 4 will analyze how each simulation fares against the developed requirements of urban combined arms combat.

Although the author has stated above that trainers should adopt a partial-task methodology, and though that may seem rather obvious to most experienced trainers, to the simulation procurement population, it would seem simplistic and almost blasphemous. They believe it blasphemous, for it forsakes the quest for the "do-everything" simulation—A model that supports all domains and all requirements, from Research and Development (RDA) to Training (TEMO) and Advanced Concepts Research (ACR). However, remembering that all simulations are models implemented over time, and that all models are inherently compromises, one can surely agree that all models must therefore have flaws. The question then becomes for the user what flaws can they live with, and what flaws become "show-stoppers."

Joint Conflict and Tactical Simulation (JCATS)

One of the most successful cross-domain simulations has been the Joint Conflict and Tactical Simulation (JCATS), which for the most part, evolved from the venerable entity-level constructive JANUS simulation originally developed in the 1970's.[37] JCATS sees a great amount of use not so much because it performs well "across the board," but because it performs generally well enough across a broad range of tasks. Originally developed to support high-fidelity RDA research, JANUS quickly became a tactical training simulation. Likewise, JCATS moved from supporting large Joint exercises to supporting smaller tactical training, and due to its interoperability with C2 systems, has become the default driver for most training involving digital tactical operations centers. Due mainly to its broad usage, JCATS has become the standard for all simulation fidelity comparisons, even though the constructive "god's-eye view" of tiny icons leaves much to be desired in compelling and intuitive interfaces. Due to its capabilities to model

[37]Faith Shimamoto, "Simulating Warfare is No Video Game." *Science and Technology Review* (January/February 2000), 4.

multi-storied buildings and floor plans, JCATS has become a rehearsal tool for conducting small-unit urban operations, even though conventional simulation training guidance states that trainers should use virtual simulations, not constructive ones, at levels below battalion. However, the virtual simulations currently fielded do not have the desired fidelity.

As with all rehearsals using models, be they clay or electronic, the executers must know the limitations of their tools. Unfortunately, when viewing the simulation real-time, much of the detail present in JCATS lies hidden inside its calculations. Although these calculations can be extracted using AAR tools, failure to do so diligently may mask important information. Furthermore, soldiers tend to fight as they train, and given a model with limitations, they may fail to plan using techniques that their rehearsal tool cannot replicate. For instance, if the simulation used for the rehearsal cannot replicate ballistic wall breaches, and only allows entries through existing windows and doors, then the training unit may eventually forget to think about realistic possibilities and become fixated on "work-arounds" required for their given system. This phenomenon occurs most frequently during live training due to the great amount of limitations of "Lazer Tag" style devices, particularly when dealing with heavy armor. No one doubts that a high-explosive round from a tank main gun can breach a wall, but when was the last time units performed it in live training at home station? Will they remember the technique when they deploy in urban combat?

Given that all models have inherent limitations, and developers must focus the purpose of the model in order to optimize its performance and minimize its limitations, to what extent have the simulations currently in use by military trainers been optimized for the combined-arms urban environment? Fortunately, the capabilities of modern computers and graphics cards have greatly increased the fidelity present in today's virtual simulations. Unfortunately, most of the virtual modern simulations in use by trainers are game-based, and have significant limitations (to be detailed in the following chapters). If the training community accepts that virtual simulations work best to replicate the battlefield environment at levels below battalion, then the community

should re-look the requirements for its virtual simulations in modeling the combined-arms urban fight.

Given that the purpose of this study is in fact to revise virtual simulation requirements, and not to actually find the best virtual or constructive simulation, the author did not feel that the effectiveness of the study relied on the inclusion or omission of a particular simulation. Therefore, the author chose an assortment of Microsoft® Windows™ PC-based simulations and games in order to arrive quickly at the destination of an improved requirements list. The chosen simulations represent a broad array of capability, from the constructive TAC-OPS, to the high-fidelity virtual simulation, Steel Beasts 2. The following simulations, when compared side-by-side, should shed some light on the differing levels of urban fidelity built into the systems based on their intended audiences and purposes. Additionally, more and more trainers at Battle Command Training Centers and trainers at deployed sites use PC-based solutions because of their ease of use, their scalability, and the flexibility of the platform to run multiple software packages. Although one cannot argue the fidelity and quality of “heavy” simulations like the Close Combat Tactical Trainer (CCTT), the sheer number and ease-of-use of PC-based simulations has overshadowed them. PC-based solutions have rapidly become the standard for most “crawl” and “walk” stages of training.

Operation Flashpoint (DARWARS Ambush!)

Bohemia Interactive™ (BI) released Operation Flashpoint (OFP) in 2001, and the defense community quickly became aware of its training potential. That potential arises from the inclusion of a very powerful scenario editor in the base release; the full interaction of realistic fixed and rotary wing aviation, armor, infantry, and artillery; as well as a terrain database limit of 100km by 100km—Huge by any standards. Operation Flashpoint stands as one of the most versatile and powerful virtual PC-sim wargames in existence. Even though newer wargames

boast better graphic resolution, they typically do so at the expense of the size of the terrain database.

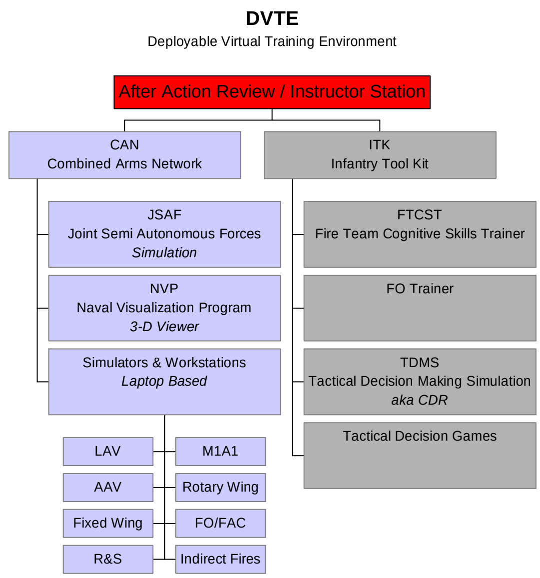

Figure 2. U.S. Marine Corps DVTE Diagram.[38]

(America's Army uses a relatively tiny terrain database, usually measured in hundreds of meters versus hundreds of kilometers.)[39]

Soon after its release, Coalescent Technologies ® purchased the government and military use rights to the Real Virtuality™ game engine, and created Virtual Battlefield System 1™ (VBS1™), which the United States Marine Corps procured as part of the Infantry Tool Kit in its Deployable Virtual Training Environment (DVTE), see Figure 2, above.[40] To date, several allied countries, U.S. military services, and several government agencies use VBS1 and its successor, VBS2 (using the updated Real Virtuality™ engine), to train small unit tactics and conduct

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[38]Michael P. Bailey and Robert Armstrong, "The Deployable Virtual Training Environment (DVTE)." *The Interservice/Industry Training, Simulation & Education Conference (I/ITSEC)* 2002, no. 2002 (Conference Theme: The Power of Simulation: Transforming Our World), 2002.

[39]Anonymous, *[Optimization] mesh size?* [Internet on-line] (AmericasArmy.com, April 14, 2007, accessed on April 14, 2007); available from http://forum.americasarmy.com/viewtopic.php?t=254169; Internet.

[40]Michael P. Bailey and Robert Armstrong, *The deployable virtual training environment* [Internet on-line] (U.S. Marine Corps Training and Education Command, June 15, 2004, accessed on January 17, 2007); available from http://www.tecom.usmc.mil/techdiv/dvtepaper1.htm; Internet, 3.

mission rehearsals on custom terrain databases.[41] In addition to the commercial release's capabilities, Coalescent added playback, instructor views (sometimes referred to as "Stealth" views) and playback to VBS1™. In a training environment, instructors value the ability to refer to game views via playback and third-person views.

The author used VBS1™ to train cadets at USMA in small unit and combined arms tactics for two years after using custom scenarios in Operation Flashpoint™. The addition of instructor tools in VBS1™ greatly enhanced the ability to conduct AARs of the training units' actions.

As part of the DARPA DARWARS project, BBN Technologies modified Operation Flashpoint™ into "DARWARS Ambush!" in order to incorporate quickly the lessons learned from ongoing U.S. military actions into small-unit training.[42] Utilizing a "mod" instead of re-writing the game code decreased unit cost of the software, and allowed military units to purchase commercial versions of Operation Flashpoint™ and apply the government-owned mod at a great savings to the unit. Although BBN did not build the same training functionality with playback, instructor modes, and AAR capabilities into DARWARS Ambush! that exist in VBS1™, the difference in cost between the two systems (DARWARS Ambush costs about $20 each PC, while VBS1™ costs over $1000 for most of the terrain databases, and the instructor functionality) makes the DARPA version available to the masses, while only well-funded organizations and simulation centers can afford VBS1™ and VBS2™. In comparison with government-developed virtual simulations, however, the cost and capabilities of the Real Virtuality™ engine compare very favorably to the six and seven digit unit cost of systems like the Close Combat Tactical

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[41]Coalescent Technologies Corporation, *VBS--US customers* [Internet on-line] (Coalescent Technologies Corporation, 2006, accessed on January 15, 2007); available from http://www.virtualbattlefieldsystems.com/customers.html; Internet.

[42]National Defense Industrial Association. *DARPA simulates convoy ambushes* [Internet on-line] (National Defense Industrial Association, December 2004, accessed January 21, 2007); available from http://www.nationaldefensemagazine.org/issues/2004/Dec/DARPASimulates.htm; Internet.

Trainer (CCTT), and SIMNET. In the commercial game sector, a successful game like Operation Flashpoint™ occurs in one in one thousand games. The natural selection of commercial games and the lack of such a phenomenon in government simulation partly explains why the interfaces and quality of some commercial games and simulations rival those of their government brethren. A very direct comparison can be made with such titles as Microsoft Flight Simulator® and its larger professional versions in use by airlines and flight schools. Since simulations released commercially rely more on public purchases than government funding, such ventures may be funded at much lower cost than those that the government funds exclusively. For relatively simple, unclassified small-unit training, modified commercial simulations can be a great bargain.

Ironically, the simulation industry championed the "discovery" of Operation Flashpoint's™ capabilities by DARPA's contractor (BBN), 4 years after the release of VBS1™ by Coalescent® Technologies. The release of the competing simulation sparked a brief legal war between the two companies, from which many declared the government the winner, because of the lower unit cost of "DARWARS: Ambush!" However, that unit cost does not include the research costs paid to re-develop the simulation for government use. Although the costs to each military unit to use "DARWARS: Ambush!" are extremely low, the money has been spent from other government accounts. In any case, the precedent set by the dual development of the Real Virtuality™ engine will likely not encourage private sector companies like Coalescent® to develop low-cost simulation options in the future—The government and military may lose out in the long term.

On the bright side, the DARWARS Ambush! program created many "Middle-Eastern typical" urban scenarios that present the user and instructor with many options, and incorporate many improvements over the original OFP. Using BI's flexible action menu, BBN added additional realism and interaction to scenarios that BI had not included in the original commercial release. These added interactions allow for more realistic urban scenarios than previously existed in OFP. For instance, in 2000, first-person shooters did not possess doors that opened and closed

via player interaction. However, by 2004, most games modeling buildings had such detail, and much more. The versatility of the Real Virtuality™ engine proved itself by allowing BBN to add opening and closing doors to the simulation without a major code re-write. The programmers simply added a command to the command window, which the system prompts based on entity proximity.

Based on the Real Virtuality™ engine capability, and the proven urban combined-arms scenarios of both DARWARS Ambush! and OFP, BI's creation answers the question of whether or not the simulation can model combined arms urban combat. The only remaining question is how well it models the environment. VBS1™ scenarios currently used by the National Guard model multiple factions and noncombatants in crowded Middle East style urban terrain. One may assume that the Real Virtuality™ engine's offspring would do well against other simulations, but that depends on the quality of the model's representation and on the metrics of comparison. These will follow in later chapters.

Steel Beasts 2 Professional

Steel Beasts 2 Professional® (SB2), released by eSim™ Games holds at its core the follow-up game engine to the 2000 Best Simulation Game. In an industry full of copycats and very few original ideas (Critics lauded Full Spectrum Warrior™ not because of its quality, but because it ushered in a new genre, which had not been seen in a decade[43]), SB2 exists as one of the true Virtual/Constructive[44] simulation hybrids.[45] In the virtual domain, SB2 allows one to act as the tank commander or gunner of any vehicle, and as the instructor, to float from vehicle to vehicle, and anywhere in between. Simulation systems such as SIMNET and CCTT have

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[43]Greg Kasavin, *Full spectrum warrior GameSpot preview* [Internet on-line] (GameSpot.com, September 22, 2004, accessed April 22, 2007); available from http://www.gamespot.com/pc/strategy/fullspectrumwarrior/index.html; Internet, 1.

[44]Defense Modeling and Simulation Office 1995, 68.

commonly referred to that view capability as a "Stealth" view. As a constructive simulation, SB2 allows complete control over the simulation from the "map" view with easy access to 3D virtual views by "right-clicking" on the unit or terrain location of interest, with the icons existing as aggregates or single vehicles.

The math behind the graphics of SB2 relies on empirical data from gunnery tables and armor penetration data. The developers used classified data in some of the limited-release professional versions specific to nationality. In fact, the gunnery tables are so accurate in SB2, that several NATO countries use it as the basis for their Leopard 2 conduct-of-fire trainers. They use modified gunner's controls and control panels to outfit the system at a very small fraction of the cost of a large, trailer-based system like the VAX-powered M1A1 UCOFTs present on many U.S. Army installations. Using the playback and AAR features, the instructor can view the trainee's accuracy and verify where the fired rounds struck the engaged targets, and view the gunner's sight picture both when he lased and fired. Additionally, since SB2 models full maneuver, the instructor may choose to create full battle scenarios not based on range roads and linear back and forth "range-ology." However, eSim™ games designed SB2 to primarily model rural and desert environments, not dense urban areas.

Unlike VBS1™ mentioned earlier, SB2 does not possess the ability to model full joint combat—yet. As the developers continue to build the code to SB2 (the current releases are pre-release Alpha builds), they introduce more capabilities into the system. Currently, SB2 can handle a 50x50 kilometer database of up to DTED level 3 (20m posts), and can also directly import DTED data as well as SHAPE files, though at the time of this research, the developers continued to build the capability to import more feature data formats. The ease of importing DTED data into SB2 allowed the author to re-create the G Troop, 2/2 ACR battle for 73-Easting

in about 2 hours, with realism that passed the inspection of the former troop commander, now COL Joseph Sartiano.[46] However, the G Troop battlefield contained no urban structures.

Though importation of terrain data into SB2 proved easy, creating a realistic terrain-specific urban model presents significant challenges. For one, the prevailing feature data format for buildings and roads has changed several times in the last decade, and conversion to a readable form may prove difficult or impossible--Hence the developers' interest in programming future feature data format compatibility.

Although SB2 stands as one of the highest fidelity heavy combat sims available, it does not currently model urban operations well due to the limitations of its infantry entities. However, the developer continues to refine the engine to allow for greater fidelity and may yet add increased urban combat fidelity to the degree modeled in the predominantly infantry simulations. A further exploration of SB2's strengths and weaknesses will be explored in later chapters.

TAC-OPS

TAC-OPS, though dated by many standards, remains one of the most frequently used military wargames in existence. Originally released in 1994 by a retired marine major, I.L. Holdridge, Fort Knox's Armor School still uses the game to teach basic tactics to captains.[47] Basically a computerized board game, TAC-OPS lacks much in the area of terrain reproduction or specificity. It models hills in "high" and "low" levels of terrain, versus actual terrain data. Though the newest version of TAC-OPS uses rudimentary map reproductions, the underlying terrain models reduce the effects to basic levels of cover and concealment.

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[46] The scenario for G/2/2 ACR was used by Dr. Rick Swain to support MS497, Battle Command, in the Spring of 2005 at USMA. COL Sartiano lectured during the colloquium, and discussed the actions of his troop at 73-Easting.

[47] I. L. Holdridge, *TacOps 4: Overview* [Internet on-line] (BattleFront.com, 2005, accessed on April 21, 2007); available from http://www.battlefront.com/products/tacops4/tacops4.html; Internet.

Military schoolhouses continue to use TAC-OPS to train leaders in company to battalion-level tactics. Its strengths lie in simulating battle of company level units and higher, due to its coarse resolution of terrain and effects. As such, TAC-OPS models combined-arms urban combat in terms of the amount of cover , so it does not model individual buildings or detailed terrain.[48]

Though TAC-OPS remains in use, the level-of-detail represented insults the capabilities of todays multi-processor PCs. Designed to be a computerized board game, TAC-OPS fulfills the requirement for entry-level tactics training, but the negation of terrain specifics and the ability to visualize the terrain in a realistic perspective limits its use to the "crawl" stage of training. Given the existence of 3D terrain modeling found in virtual simulations like SB2, sales of TAC-OPS have declined to the realm of the hard-core wargamer and military schoolhouse, while the commercial mass-market has moved on to simulations offering a more compelling experience.

Close Combat--Marines

When it debuted as a WWII real-time tactics (In the genre of Real-Time Strategy, though without resource-building requirements common of most RTS games[49]) game in 1996, Close Combat (CC) broke new ground by incorporating a morale model and believable AI into a compelling WWII war game.[50] Unlike TAC-OPS, time does not stand still for the units to receive orders in CC. The player must think ahead, and make quick decisions to save his forces and achieve the mission. Like TAC-OPS, one plays CC from a gods-eye view, making it a

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[48]Marty McKone, *PC game preview: TacOps 4.0* [Internet on-line] (Wargamer.com, August 1 2002, accessed January 13, 2007); available from http://www.wargamer.com/reviews/tacops_4_preview/default.asp; Internet, 2.

[49]Andrew Park, *Q&A: Close combat to get new lease on life* [Internet on-line] (GameSpot.com, October 20, 2006, accessed January 13, 2007); available from http://www.gamespot.com/pc/strategy/closecombat/news.html?sid=6160284&om_act=convert&om_clk=mostpop; Internet, 1.

[50]Kevin Mical, *Close combat* [Internet on-line] (GameSpot.com, August 1 1996, accessed February 20, 2007); available from http://www.gamespot.com/pc/strategy/closecombat/review.html; Internet, 1.

constructive simulation by DoD standards in the same realm as JCATS and TAC-OPS. However, the units in CC are not aggregated as in the other two simulations, although their movement and commands are given at the unit level (usually fire-team or vehicle). Soon after its arrival on the market, the U.S. Marine trainers at Quantico noticed its potential, and approached Atomic Games to modify it for Marine training use. Within a few months, Atomic released Close Combat—Marines (CCM), a modern Marine version of the original, to the Quantico schoolhouse. The British Army and the United States Military Academy (USMA) (under the former direction of this author) use modifications of the Marine Corps version for small-unit leader training.

CCM's interface gives the user a very good view of the battlefield, but the single overhead view masks the subtle elevation changes that make the difference between maneuver and suicide on the battlefield. Additionally, though CCM allows for the use of multi-floored buildings and partial cover, the effect appears to be minimal and transparent to the user. Furthermore, most scenarios used in CCM cover only a 2-kilometer square box of terrain—an area smaller than the range of a tank round.[51]

Although CCM has great limitations by today's large-database virtual simulation standards, at the time of its release in 1996, its level of realism and simplicity made it a best-seller. CC maintains a fan-base that creates "mods" and custom scenarios to this day.[52] As a testament to its popularity, the developers that adapted the original Close Combat for Marine Corps use, have re-released the Close Combat simulation as Close Combat: Cross of Iron[53], which features some updated code and better Windows™ compatibility, but keeps the essence of the original game play (and the 2D environment)[54].

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[51]Michael Woodman, Don Mathes, and Jim Redmond, *Letter Of Instruction For Training With The Infantry Tool Kit (Itk) In Infantry Cognitive Skills Training Labs*. (Unpublished memo, 2002), 7.

[52]Park 2006, 1.

[53]Matrix Games, *Close combat--cross of iron* [Internet on-line] (MatrixGames.com, 2007, accessed April 25, 2007); available from http://matrixgames.com/games/game.asp?gid=335; Internet, 1.

[54]Park 2006, 1.

Given that the Marines utilize CCM for junior officer and staff NCO training in basic tactics, the limitations of the simulations models do not create a limit to training. Essentially, the Marines use CCM as the "crawl" stage of tactics training. Likewise, USMA used the game to support instruction for its second-year cadets, who were just learning to maneuver a fire-team and squad. As far as adequately modeling modern urban combined arms combat, however, the CCM model, along with the other simulations, falls short. Chapter 4 will further explore this shortcoming.

CHAPTER FOUR

COMPARISON METHODOLOGY

Since this study has already concluded that no selected simulation adequately models the combined arms urban environment, it begs the question, "Why conduct a further comparison?" Since the selected models all have different strengths and weaknesses, a comparison allows the reader to see whether the simulations may be usable for a given task. A comparison also highlights the trade-off decisions that the designers made in the development of each simulation.

The Issue of Model Validation and Requirement Generation

In comparing various models that differ in both domain as well as capability, the author decided to utilize an accepted list of requirements developed by the Institute for Defense Analysis (IDA) to perform a baseline comparison. IDA developed this list to support verification and validation of the JCATS simulation for urban environments.[55] IDA built the requirement list from historical events and from Subject Matter Expert (SME) opinions of what the model needed to include in order to represent reality adequately. In other words, IDA attempted to validate the model against the real requirements of combat. Government agencies frequently call on SMEs to evaluate systems and vet requirements. The researchers prefer this method because it yields answers quickly, and in some cases can generate credibility that the system in question performs to an accepted standard--If that standard is indeed an *accepted* standard. An example of the IDA report validation question is the following: "Does JCATS adequately represent a MOUT environment?"[56] The IDA SMEs rated this question on a scale of 1 to 5. This question becomes more of a "Turing Test" than a simple "yes" or "no," and the experimenters assumed that the SMEs inherently know what the requirements to represent a MOUT environment are. Though a

[55]Christenson et al. 2002, 10.
[56]Christenson et al. 2002, 227.

widely accepted technique, the solicitation of SME feedback in the form of surveys such as the one used by IDA can generate some fallacious conclusions. For instance, if the average score for a given question is 4 (5 being most positive), does the model adequately represent that requirement? Mathematically, the answer is "yes," but the assumption inherent in the process is that each SME implicitly understands the model fidelity requirements of the environment in question. Again, mathematically, the numbers work out in large enough groups due to the Central Limit Theorem and use of repeated measures to make up for human variance. Logically, though, do 30 answers of "sort-of supports" (a score of 4) average out to "supports?" Do simulations "sort-of" pass their requirements before fielding? Too often that answer is, "Yes."

Additionally, in practice, the SMEs very often tend to mix "wants" with "needs" in their internal analysis of model requirements, and increase the model requirements to where only reality can adequately replicate reality because the available computing systems cannot handle the required calculations. Additionally, SMEs frequently add personal bias to studies, due to their desire to only conduct "Live" training, and not be forced to use virtual or constructive simulations. The system proponent managers have not helped reduce this belief, and have in the case of the Tank Weapons Gunnery Simulation System (TWGSS), traded live main-gun training rounds to pay for the simulation. This action left a bitter taste in nearly every tank sergeant's mouth, and generated a bias against further simulation fielding since the arrival of TWGSS in 1995.[57]

In conclusion, though frequently used and at times effective, developers should use SMEs sparingly and give them clear, unambiguous guidance when using them to validate simulations against combat requirements.

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[57]Bonnie Harrison, *Tank weapons gunnery simulation System/Precision gunnery system (TWGSS/PGS)* [Internet on-line] (U.S. Army Program Executive Office for Simulations, Testing, and Instrumentation, Aug 11, 2004, accessed February 19, 2007); available from http://www.peostri.army.mil/PRODUCTS/TWGSS-PGS/; Internet, 1.

Method of Study

This study takes a different approach to generate requirements—historical case studies. Many past studies have used historical approaches to validate their simulations with specific, well-studied, historical battles. These studies essentially aim to recreate as accurately as possible the historical battle, thus postulating that if the model can accurately recreate a historical event, it must be valid for the given use. This study differs in that approach in that it will gather the tactics and techniques used in the selected historical battles in order to generate modeling requirements for that type of warfare. An opposing view of the use of historical accounts of battles may state that they may focus the attention too narrowly on specific areas that no longer factor in modern combat. However, the use of historical accounts focuses the requirements on a greater amount of factual data, and thus avoids some SME (human) bias.

For this study, the author created a table indicating whether or not one of the above five simulations met or did not meet the urban combat simulation verification requirements as stated in the IDA report. As stated earlier, the comparison's purpose is to create a basis for discussion and to aid in generating additional requirements based on each simulations' strengths or weaknesses. For example, if a given simulation models dynamic building roofs, which allows for a ballistic breach from above, that capability may be advantageous in future model development because it allows for combat between floors and can aid in running realistic rehearsals of building seizures by special operations forces. In addition, the use of the verification (used to test whether or not the model meets the design requirements) versus the validation (whether or not the model is "good enough" to be used for the stated purpose) criteria lends some added rigor to each model's examination.

The listed requirements from the IDA report are the following:

MOUT Capabilities from JCATS V&V Report

The IDA report from Christensen et al. broke the required capabilities into the following ten categories (see Appendix A for the full listing):

1. Dismounted Combatant
2. Combat Inside/Around Buildings
3. Combined Arms/Joint Force
4. Command, Control, Communications, Computers, Intelligence, Surveillance, Reconnaissance (C^4ISR)
5. Rules of Engagement (ROE)
6. Subterranean
7. Non-Lethal and OOTW
8. Treatment of Vehicles and Aircraft
9. Terrain
10. Technical Considerations

1. Dismounted Combatant

Under the category of Dismounted Combatant, IDA listed the following requirements:

11. Postures (Standing, Kneeling, Running, Crawling, Prone, etc.)
12. Wounding, Tie-in to Terrain (fidelity and resolution of the terrain database)
13. Suppression: human response, Interaction with vehicles (mount, ride on top)
14. Weapons Effects
15. Movement
16. Sensing and Direction
17. Fatigue and Stress

The dismounted combatant category remains one of the largest categories due to the fundamental involvement of infantry in all urban actions. The historical battles discussed above in this document reinforce this fact. Although Christenson and the other IDA authors listed the needed capability to represent infantry ballistic wall breaching in their report, they did not include it on their requirement list in the final report. The omission of that key, but nearly impossible requirement appears to be more than a simple mistake. They chose not to highlight the simulations key deficiencies. Although this may seem like a showstopper considering current operations in Iraq and Afghanistan, and the need to train forced building entries, JCATS stands with most simulations in not modeling dynamic terrain or terrain features. Dynamic terrain

stands as one of the simulation world “Holy Grails.” Eventually, with enough processor power and main board memory, simulation will be able to run large dynamic terrain databases. In fact, some simulations and games running small databases have had dynamic terrain features for some time. Knowing the near impossibility of the task, Christenson et. al. probably left the ballistic breach requirement off the list so as not to needlessly lengthen the document. Currently, Soldiers training to conduct ballistic breaches solely use live training methods (live fire) to gain task proficiency, missing opportunities to drill established TTPs during digital networked training exercises.

2. Combat Inside/Around Buildings

The building category seen in the below list mainly addresses the effects of buildings on entity capabilities, rather than the fidelity requirements of the simulation in modeling the buildings themselves. While this omission may not seem too important, given the current lack of stairwells and elevators from the JCATS model, the omission’s effects become more severe.

1. Shell of Building (Blocks Movement or LOS)
2. Rooms and Floors (Shape/Structure, Furniture)
3. Stairwells and Elevators
4. Exterior/Interior Wall Materials and Effects on Munitions/Demolitions
5. Rubbling effects on Mobility and LOS
6. Windows and Doors (Effects on pass/see/shoot through)
7. Interior Illumination/Temperature
8. External Walls and Windows: firing in and out
9. Texture to External Buildings
10. Covered Concealment Around Buildings
11. Use of UGV (Unmanned Ground Vehicle) Inside Buildings

When clearing buildings in a built-up area, infantry must utilize stairs, elevators, fire escapes, and other means of gaining access to floors. Due to this, building defenders frequently base their plans off retaining or denying use of stairwells and fire escapes. Additionally, but not mentioned in the main table of requirements, entities in the simulation must be able to fire up and down stairwells and elevator shafts , as well as otherwise fire between floors. This may seem

simple, but in many legacy simulations, the elevated floors of buildings are essentially modeled as the ground, and are relatively impenetrable. Modification of this code requires much effort on the part of the developers to gain an ability inherent in most virtual 1st Person Shooter games played by teenagers, to include OFP.

As in all successful urban operations since WWI, tanks and vehicles interact (violently) with buildings in order to destroy enemy strongpoints and to gain access to buildings from other than established doors and windows. As in the case with stairwells and elevators, building defenders plan their defense around existing windows and doors. Current four-man stack tactics derive the idea of the "fatal funnel" from this tendency. Thus, attackers frequently avoid defended doors and windows by conducting "ballistic" breaches through walls and roofs of structures at a place of their choosing. One of the best methods for doing this is with vehicle-mounted weapons. In the case of the M1 Abrams tank, the MPAT and canister rounds make very large holes in walls suitable for infantry to conduct such breaches. Unfortunately, the ability to modify walls and building roofs in real-time continues to be one of the largest challenges in simulation—at least simulation used for research. Although such common games as Half-Life 2™ allow for modification of objects depending on their material, the buildings and base terrain of the model still do not allow for dynamic changes—i.e., blowing a hole in a building or roof at any place of choosing. Ironically, MechWarrior 3™ (MW3), released in 1999, utilized a limited implementation of dynamic terrain and buildings. In MW3, large HE rounds make craters in the terrain, which entities can use as firing positions. The game actually modifies the terrain, a feat which many SMEs of military simulation companies say lies in the realm of the impossible. Weapon strikes in MW3 break bridges and buildings into large parts, but not in the complex manner allowed in newer engines such as the Source® engine used in Half-Life®2. Still, MW3's eight-year-old dynamic terrain (which runs very well on a high-end Pentium 2) stands as a contradiction to what most simulation experts state cannot be done on today's professional multi-processor workstations.

Training requires less of a simulation, with regard to modeling full reality, than a research simulation does—a very important distinction that shall be discussed more later.

3. Combined Arms/Joint Force

1. Indirect Fire (Includes Terminal Guidance of Smart Munitions)
2. Aircraft (CAS, Helicopters, UAVs, LOS, Vulnerability, ADA)
3. Armor (Capability and Vulnerability)
4. Naval Forces (Munitions and Targeting)

The use of combined arms and joint fires in an urban environment seems like an addition to the normal infantry-centric doctrine and training performed by the United States in the last few decades at locations like Fort Polk and Fort Pickett, VA. However, in the realm of simulation, the interaction between tanks and buildings stands no different than the interaction between infantry and buildings. In both cases, entities (infantry or tanks) interact with features (buildings) or objects, *if* the simulation uses dynamic features.

In the case of JCATS, which largely explains why this category exists in the Christensen study, buildings posed a greater challenge to model due to the lack of floors and the ability of entities to fire out of uppers stories or the roof of the structure. Obvious to most military veterans, terminal ballistic effects of anti-tank rounds change greatly when they are fired onto the top of a vehicle versus the sides, front, or rear. Simulations must be able to support the difference, and for JCATS, the change in code to allow such differences required a great effort.

The remainder of the Combined Arms and Joint Force requirements involve generally involve the ability of the entities to spot or act as forward observers or conduct terminal guidance for joint fires.

4. C4ISR

1. Command and Control
2. Communications (Voice, Gestures, Radio, Transmission Reliability, etc.)
3. Integration of Air/Space Intelligence Means
4. Use of Sensors for Surveillance (Air, Ground, National Sources, Thermal, Radar, Sound, Visual)
5. Integration of Joint C4ISR

For most simulations, the interaction or inclusion of C4ISR exists as injects or the appearance of map or graphical icons in the heads-up display. For constructive simulations and simulations used in research, the requirements become greater because of the simulations near-autonomous behavior. For virtual simulations and training, much data C4ISR appears to the user imbedded in verbal and graphical messages. Gestures stand as an exception, but many new virtual game engines allow for detailed entity gestures to take place between users using simple key or macro commands. For many training units, the inclusion or compatibility with existing C4ISR programs, such as Army Battle Command System Version 6.4, becomes paramount.

Although C2 compatibility acted as a show-stopper in the past by limiting the use of PC sims such as SB2 in training, the growing tendency to make or convert PC sims to High Level Architecture (HLA) compliance will allow for simulation to C2 stimulation--At least in theory. HLA compatibility, though originally designed for simulation inter-operability, also allows for the communication between C2 and simulation systems. One may not see the simple relationship, but C2 systems and simulations differ very little in that both systems involve a database changed over time. The main difference lies in what process changes the database. Whereas simulations change the database from internal inputs (and sometimes external simulations), C2 systems use mostly external inputs.

The issue of HLA compliancy deserves some special discussion due to its overuse and exaggeration by simulation companies. While two simulations (called federates in HLA-speak) may indeed be both compliant, they may not be compatible due to their use of different

Federation Object Models. The required translation between the two federations may require extensive use of gateway software and hardware, and may result in costing more in software licenses, hardware, expert man-hours, and time than the simulations did in the first place, particularly if these simulations are PC-based like VBS1 and SB2. Granted, some HLA programs are more compatible than others, but that compatibility needs to be verified before assuming that the programs are indeed compatible, and to what degree.

In any case, few simulations easily integrate with C2 systems. When such systems do exist, the interoperability usually exists only as long as the version number of both systems stays the same. Gateway systems, though cumbersome, and expensive to operate in both time and personnel, usually work better in the long term than changing simulation code to adapt to the rapidly changing world of digital C2. As hard as interoperability may be, implementing a C2 emulator within the simulation is much, much harder. Since each simulation typically uses a different engine, the creating a emulation of a current system must be coded specific for that system, and then must be kept current with the specific C2 systems in order to maintain training effectiveness. With any method, maintaining integration or inter-operability with C2 systems stands as one of the hardest tasks within the training and military operations realm of simulation.

5. Rules of Engagement (ROE)

1. Number of Sides (To include Neutral/Hostile and Neutral/Friendly, and whether or not sides can be changed in real-time)
2. Hold Fire Capability (No-Fire, Return Only, and Pre-Emptive)
3. No-Pursuit/No-Fire Zones
4. Limitations on Munitions/Platform Use
5. Prisoners of War (POW)
6. Resupply of Neutrals

With the new focus in U.S. military doctrine towards stability operations, the old training paradigm of just “Red & Blue” forces has become obsolete. Today’s operations involve numerous neutral, neutral/friendly, neutral/hostile, and allied forces. Simulations must be able to

model the numerous “sides” involved in conflicts. JCATS and many other modernized simulations allow for multiple user-set sides, typically ten or more, to include “white” and enough different allied and neutral sides to allow for the representation of most if not all allied forces present in the exercise.

With the continuation of UN, NATO, and coalition operations, nation-specific ROE has begun to hamstring operations due to one or more countries frequently “opting-out” of specific activities or operations. Simulations should be able to model different ROE for each non-human affiliation or side. Such ROE must be able to be programmed with sufficient detail to allow the simulation to pass the Turing Test.

6. Subterranean

1. Construction of Underground Structures
2. Movement (Speed and Canalization)
3. Sensing and Sensors
4. Communications Effects
5. Weapons/Munitions Effects
6. Environmental Effects (Explosive Over-Pressure, Concussion, Humidity, etc.)

The average observer may not understand the importance of subterranean effects to a list of requirements of urban warfare, but the enemy use of underground passages and the existence of large, complex caves in Afghanistan requires that soldiers and thus units in training become proficient in navigating and operating in subterranean environments. Developers built most older simulations with a distinct ground level, and though one could sometimes find themselves below the level of the ground looking up (particularly in the early SIMNET years), the simulation contained no capability for underground systems nor a way to adjudicate interactions in small underground spaces due to collision errors with underground features. Granted, the obstacles that programmers had to overcome to allow for subterranean structures, pale in comparison to the obstacles lying in the path to dynamic terrain. However, some of the code involved with making terrain below “ground” level also allows terrain to be modified with craters extending below the

surface. The obstacle to dynamic terrain resides in the current inability to modify the terrain database. The terrain database, a very large file which the system loads separately from the database objects, does not normally change during the course of a scenario run.

7. Non-Lethal and Stability Operations

1. Incapacitate Individuals
2. Disable Vehicles
3. Simulate Non-Lethal Weapons Effects

At least in the eyes of this author, the incorporation of non-lethal effects into simulation code poses few problems for the programmers. Most warfare simulations already allow for degradation of combat effectiveness through either suppression or wounding, so the additional coding of a non-lethal weapon that creates "wounding" effects seems simple. Similarly, most current simulations include a relatively decent model for vehicle damage. The issue becomes to what degree of fidelity the system will represent such limited weapons in the database. As ever, the user must make the decision as to what fidelity he needs to effectively represent the situation. Research tasks will require greater fidelity than common training tasks, where the appearance of reality (the suspension of disbelief) equals reality for training effect.

8. Treatment of Vehicles and Aircraft

1. Hulks (Creation and Effects on LOS and Movement)
2. Ground Movement Sensitive to (Building Clearance, Trafficability, and Road Width)
3. Air Movement (Flight, Landing, and Helicopter Flight)
4. Modeling of Platform (Sensors, Degrees of Freedom on Articulation/Traverse, and modeling of Crew)

The fidelity to which vehicles and aircraft have been represented in virtual simulations in the past few years has grown greatly since the late 80's and SIMNET's simple colored polygons. The aircraft in VBS1 have articulating flaps, landing gear, and if you look in the cockpit at a human-played pilot, you will see his head move to match the operator's gaze. Most situations do

not require that level of model realism, but it comforts most techies to know that since six-year-old PC games can model entity and vehicle articulation, modern professional servers and workstations should be able to, as well.

9. Terrain

1. Dynamic Terrain
2. Terrain Resolution
3. Buildings
4. Subterranean Features
5. Cultural Features
6. Vegetation

Though terrain in Christensen's list rests ninth in the order of categories, the issue of Dynamic terrain remains on of the most, if not the most, difficult requirement to achieve. Yet, the lack of it in an urban combined arms simulation decreases the training effect possible by using the simulation. As more urban combat actions occur, the requests for dynamic terrain in training exercises to enable modeling of non-standard ballistic breaches, destruction of caves, and novel forced entry techniques will continue to increase. In the same regard, the simulation terrain and feature databases (both of which most simulations load up front separate from the entities and objects due to size) must allow for realistic vegetation that not only blocks LOS and effects projectile flight, but also degrades or interacts with entity actions. For instance, high-explosive rounds should knock down trees, and they should fall when engineers use chainsaws to clear fields-of-fire. Although not as important as dynamic terrain, vegetation will eventually become an important simulation topic.

10. Technical Considerations

1. Programming Language
2. Type of Computer Employed
3. DIS/HLA Compliant
4. Interactive vs. Closed
5. Immersiveness
6. Real-time
7. Data Tools
8. Control of Variables
9. Built for Training or Analysis*
10. Ease of Expansion/Modification

As discussed in some detail earlier, technical considerations reign supreme when conducting training either using large databases requiring significant time to build or interoperability with other dissimilar simulations or C2 systems. The sheer size of a database required for a BCT or larger unit's training event requires that the event planner either use pre-existing data or create a database far enough ahead to allow time for development, integration, and testing. Though JCATS uses C++ as its core language, the interface for changing the simulation database defines the word "difficult" by being both hard to use and unforgiving of errors. In contrast, some newer simulations have simple scenario development interfaces, while others have more advanced and very complex systems.

Most 15-year boys understand what "PC-based" means, but somehow that definition implying MS® Windows™ compliancy and single-machine capability does not enter into the buildings where employees for professional simulation companies work. To them, their $10 Thousand Linux-running, multi-processor driven workstations fall into the "Personal Computer" realm, even if the simulation takes multiple such "PCs" to operate. Bottom Line: One has to ask specific questions when it comes to hardware and software requirements for simulations. While game-based simulations will run on Windows PCs, upgraded legacy simulations originally running on UNIX workstations will rarely run on Windows, and frequently seem to find the existing instabilities in the system. While it is true that Linux runs more stable than Windows,

Windows compatible software works on virtually every computer in a military unit, usually with no modifications of the system, thus increasing the possible available training devices to a given unit. With PC-based simulations, a unit could potentially use every available computer as a training device.

The degree or lack of compliancy with DIS and HLA standards imply inter-operability with more than just C2 systems. Ever more frequently, simulation centers tie virtual simulations together with constructive, and link them together with live training to stimulate the C2 systems for a unit's battle staff. Again, while HLA compliance seems to be a solution to gaining inter-operability of models, at the core of the HLA standard lays a simple requirement to document the manner and language that the simulation uses to talk to itself. The actual act of transforming this data into a different language for a different system falls to a Run-time Infrastructure (RTI) that must be kept current and updated to allow for continued usefulness.[58]

Christensen's and his team used whether a simulation supported both training and analysis as a requirement for JCATS. Though desirable from a purely fiscal point of view, the technical requirements for an analysis tool vary extremely from those of a training tool, and frequently diverge. While a low-fidelity dynamic wall that supports ballistic breaching, but does not exactly model the effects of the breaching explosive supports training, researchers using the tool for analysis gain little to no insight from it whatsoever. Another issue is that many requirements have been "poo-pooed" as being too hard, because for an analysis sim, it has to be perfect, or it is not good enough. For a training sim, the Turing Test provides a good enough solution. However, many program managers of analysis simulations remove requirements that the product cannot precisely meet. Frequently, developers, whether they be program managers or the code-writers, also reduce requirements due to system, time, or budgetary limitations. Users

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[58]Balaji Natarajan, Shrideep Pallickara, *JSDA, CORBA and HLA-based mutechs.* [Internet on-line] (Syscon.com, April 1, 1999, accessed February 17, 2007); available from http://opensource.sys-con.com/read/36342.htm; Internet, 1.

must then re-discover the need for the requirements, and strive to get the capabilities added to future models. This is the case with capabilities like dynamic terrain. Though limited capability exists in PC-games the last several years, the biggest hurdle for military simulation has been the lack of available processor power to create the needed fidelity for both analysis and training. Sometimes a universal tool (a simulation that supports both training and research) is not the best one for the job.

The ease to which users can expanded or modify a model seems to increase over time. Initially, the developers are loath to release the development kits for a simulation, particularly a game, because they desire to maximize profit, and keep the consumer interested in sequels and expansion packs. Likewise, many simulation companies that use proprietary software prefer to keep the editing tools to themselves. Later, when use of the simulation or game becomes widespread, the companies frequently release the Scenario Development Kit (SDK) to further increase interest by fueling third-party scenario development and fostering a community of users that trade models and scenarios with each other. This phenomenon occurs more frequently with wargames like TAC-OPS, but in the case of OFP, Bohemia packaged a very powerful SDK with the game release, and about three years later, released the full development kit required to change the basic appearance of much of the interface and to create base models themselves. In this way, users created a call-for-fire function, improved the operation of the map grid to more closely match that used by the military, and modified the command window to allow for the opening and closing of doors. Having the developer kit allowed Coalescent Technologies™ to implement instructor tools and enhance the menu system to allow a single instructor to gain different views of the virtual battlefield and control soldier logon and position assignment (side, unit, and duty position) without leaving his controller computer—a feat that few systems support.

CHAPTER FIVE

ANALYSIS

Using the requirements listed above, the author compared each selected simulation to the criteria and annotated the results in the chart in Appendix A. Following this comparison and with insight gained from past historical urban battles outlined earlier in this text, the author made further recommended additions to the requirements for simulations to model the combined arms urban fight. See Table 1, below, for those requirements.

Review of Simulations

As can be seen from the results in Appendix A, for most categories, JCATS met the requirements. Surprisingly, though in most areas other than Subterranean and C4ISR, OFP and VBS1 modeled as many, and in limited categories, the BI engine modeled more. A very important caveat to that finding is the level of fidelity modeled and the purpose of the two simulations. For many of the requirements, the OFP/VBS1 model approximated the criteria very loosely, whereas JCATS models with very tight algorithms designed for laboratory and acquisition research. However, given that the focus of this study rests in the training and military operations domain of simulation, the inclusion of high-fidelity modeling becomes less important. For training small units, the suspension of disbelief presented by the models in OFP/VBS1 works as effectively as the more precise models presented by JCATS. This is given that a trainer remains in the loop with the training unit using VBS1, and that the scenario does not require the integration of C4ISR devices. Though the development of HLA and DIS compliancy may allow C4ISR devices to communicate with VBS1 and DAR-AM, the actual implementation of the solution could be costly, involve the development of third-party solutions, and in the end, may not work. In the field of simulation inter-operability, untested claims mean little.

Though some may be surprised that the performance of a PC-Based simulation evaluated solely for the representation of requirements could do so well, the performance of

OFP/VBS1/DAR-AM exist as a testament to the performance of the Real Virtuality™ engine—A seven-year-old engine! Currently, game engines allow for much more building and subterranean realism, though most lack the total package found in OFP's engine. Fortunately, Bohemia Interactive released an update to the engine in February 2007, though that arrived too late for this study (See Figure 3). Nevertheless, in each area that VBS1 scored weak, there exist games and simulations that perform relatively well. How well each system scored with regard to the recommended requirements in Table 1 will be discussed later in this chapter.

Figure 3. Screenshot of Armed Assault™.

As far as the other simulations go, SB2 scored relatively well considering that, like the heavy armor units of the U.S. Army in the 1980's, that simulation focused on rural battlefields, and not urban. Nevertheless, few companies continually improve their products as much as eSim™ Games, so time will tell how well future versions of SB2 model urban combat. If eSim™ models urban combat as well as they modeled vehicle behavior, the result will be extremely good.

TAC-OPS and CCM, though legacy simulations, still support training at military schoolhouses. Though the simulations still support the training and education objectives set forth

in the curriculum, there exist better, more compelling tools to accomplish the goals. Additionally, the training of tactics on a "flat planet," which both TAC-OPS and CCM depict, though simpler to learn, leads trainees down the path of following procedures versus analyzing each situation based on the factors of terrain and its effects on the battlefield. Discounting the primacy of the "land" in land warfare, though relatively effective at the basic levels, can eventually become detrimental if not corrected by supplemental training materials and techniques.

Recommended Requirements

Table 1. Recommended Additional Simulation Capabilities

Recommended Additional Capabilities	**JCATS**	**OFP/DAR-AM**	**SB2**	**TAC-OPS**	**CCM**
□Spider hole firing points in urban walls at street level. From Hue					
□Multi-level buildings:		x			
□Dynamic structures (wall and ceiling ballistic breaching)					
□Dynamic Bridge Destruction and Laying	Destruction	If modeled as object			
□Hydrodynamic effects on river crossing and mobility of banks		Rudimentary			
□Burning Buildings and pill-box fortifications: Manila --modeling of flammable materials					
□Import rapid terrain and feature data	Format dependent		x Developing capability		
□Civilians	x	x			
□Civilians mixed with enemy	x w/ Fratricide turned on	x	x		x AI targeting
□Factions	x	x Rudimentary		x	
□Changing sides (terrorist fading back into pop.) From Beirut	I/O intervention	x	Work around		
□Playback		x newest VBS1	x		
□AAR support capabilities		x Simple	x Data	x Score	
□Car Bombs		x Simple			
□Full tank ammunition modeling (cannister, MPAT)					

None of the tested simulations adequately model combined arms urban combat. In order to fully model the manner in which forces fight in combined urban environments, and to avoid negative training by allowing units to train as they will fight, developers should add the additional requirements above to the requirements documents for future simulations and software updates. The use of key historical accounts to derive simulation requirements differs from the common practice of deriving requirements from training exercises and SME market surveys. In the case of the Christensen et al., study, the authors discussed validation of models using historical records, in order to see if the model could recreate history. This study differs by essentially using history as the market survey for what tasks and capabilities simulations should model.

By far the most important feature of urban operations remains the existence and modeling of buildings. It may surprise many that VBS1 outperforms JCATS with building resolution, but JCATS does not even represent stairways accurately. In VBS1, as in most virtual "first-person shooter" games, the entities walk up and down stairways, continuously. However, without dynamic terrain, even the best models cannot accurately represent the creation of spider holes in walls during the simulation run-time. If the terrain editor in a given simulation can add such holes to buildings, and if the simulation treats such holes as windows, then the entities should be able to fire out of them in a realistic fashion.

With regard to multi-level buildings, although CCM graphically depicts multiple stories, the entities simply occupy the building without regard to floor. As discussed earlier, elevation in urban environments changes the dynamic of combat greatly.

The importation of "rapid" terrain data really refers to the compatibility of the simulation software with the dominant terrain and feature file formats. If the systems are compatible, the

user can “rapidly” import the files. This requirement made the list due to the emphasis it receives in deploying units.[59]

For any given training event, the ability to learn from mistakes and the success of others remains the most important part of the exercise. Most commercial war games lack a useful AAR and Playback tool, but SB2’s tool allows for an extreme amount of interaction and presents simple, useful data. The instructor can literally fly around the battlefield after the simulation run has stopped to look at the terrain from any angle and altitude. Additionally, the instructor can also use the map to view the playback, and observe a view much like that of a ModSAF controller screen in CCTT.

The remainders of the recommendations requiring explanation involve the great “Holy Grail,” Dynamic Terrain. As mentioned earlier, many units conduct ballistic breaches into heavily defended buildings, yet most models do not support such activity. Additionally, models should support the partial destruction of walls by vehicle weapons, specifically tank cannons with full ammunition availability. In the same realm as partial destruction of building walls and ceilings through breaches, simulation should model the burning of structures, to include the associated smoke and obscuration. Most likely, the simulation must model the building material (wood, metal, etc.) for this to be possible. The bottom line is that for simulations to implement dynamic terrain, the buildings and most of the environment must be modeled as objects with object properties. More objects typically mean more processor work. However, emerging technologies exist which may allow for the achievement of King Arthur’s quest.

[59]Christenson et al. 2002, 6.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study reviewed several selected simulation from different domains, all which displayed a different approach to modeling warfare. However, when all the simulations were compared against a requirement list to model urban warfare, they all failed many categories. In summary, *there exists today no simulation that adequately allows soldiers to train "as they fight" in urban environments*.

Emerging technologies may, if implemented, solve this problem. The same approach that allows Google Earth™ and Windows™ Live Local to refresh individual map tiles instead of the entire map may aid in reducing the processor requirements for dynamic terrain. Instead of refreshing the entire terrain database each time an object changes, the simulation could only renew that area that entities currently observe. That idea introduces news problems of what happens when entities swarm an area like what happens in a major urban offensive, ala Falluja. In that instance, the simulation could dynamically allocate processor power based on a "Butterfly Grid" type algorithm, which business and game servers used to maintain redundancy and consistent performance since 2002.[60] One important point to remember is the following: The purpose of the simulation matters. A modified PC-game can probably achieve the fidelity needed to model a ballistic breach in a virtual simulation used for training. The fidelity needed for analysis may not be easily reachable, and probably cannot be achieved in real-time at all. In order to put the best possible training devices in the hands of our soldiers, and to allow them to

[60]Will Knight, *Supercomputing platform built for gaming* [Internet on-line] (NewsScientist.com, May 9, 2002, accessed February 22, 2007); available from http://www.newscientist.com/article.ns?id=dn2266; Internet, 1.

train as the fight, the bridge between analysis simulations and training simulations must be blown. The two domains need different simulations. There cannot be one for all.

Due to time and resource constraints, this study did not include all simulation candidates. In addition, many simulations emerged on the market in the time this study took place. Specifically, VBS2™ (Real Virtuality 2™) deserves an evaluation to see how much the urban capability has improved. Coalescent Technologies™ claims that VBS2™ will have deforming terrain, which may approximate dynamic terrain in some regards.

Recommendations for Future Research

As processing and graphics rendering power continue to increase geometrically, researchers should continue to study the field of simulations developers produce to entertain and train. Of specific interest will be the continual improvement of Steel Beasts 2™, the use of Armed Assault™ for training, Virtual Battlefield System 2™, and Coalescent Technolgies'™ new DIS*MOUNT™, their replacement for VBS1, based on the Torque™ engine.

This study approached the topic of requirements development through a multi-disciplined approach. In future studies and analysis, researchers and developers may want to draw on the vast resources and expertise of the Combat Studies Institute and the increasing number of studies emerging from the Middle East Theater authored by the Center for Army Lessons Learned, and other independent and non-military affiliated authors. Using such sources to build modeling requirements may help future training close the gap between reality and simulation.

Though some may find continual fault for not studying specific simulations, the goal of this study aimed to revise urban warfare simulation requirements, not necessarily to state which simulations performed better than others did. If this study aids in the development of future simulations or modifications to current simulations that increase their effectiveness in training troops, then it succeeded.

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APPENDIX: MODEL REQUIREMENTS

Model Capabilities	JCATS	OFP/DAR-AM	SB2	TAC-OPS	CCM
1. Dismounted Combatant					
Postures:					
standing	x	x	x		x
kneeling	x	x			
crawling		x	x		x
prone	x	x	x		x
foxhole	x		x (fighting posn)		
running		x	x		x
walking		x			x
Wounding:					
KIA (Killed in Action)	x	x	x		x
mobility	x	x	x		
casualty evacuation	x	x			
Tie-in to Terrain:					
1-meter digitized	x	?	DTED 3		
covered concealment		x	x		x
interactive with rubble fences, buildings, etc.		x	x		x
Suppression: human response		?		x	x
Interaction with Vehicles:					
mount/dismount	x	x	x	x	x
ride atop/outside		x			
Weapons Effects:					
infantry small arms	x	x	x		x
automatic weapons	x	x	x		x
area and directed fire of direct-fire weapons	x	x			
hand grenades	x	x			
mines	x	x	x		
claymores	x	w/a			
Movement:					
impediments to dismounted movement	x	x	x	x	x
automated taking cover	x	x	x		x
automated “pop-up” from cover	x	x	x		x
automated attack movements	x	x	x		x

Model Capabilities	JCATS	OFP/DAR-AM	SB2	TAC-OPS	CCM
Sensing and Detection:					
sound ranging and direction	x		x		
naked eye	x	x	x	x	x
effects of vision devices	x	x marginal	x	x	
smoke and obscurants	x	x marginal	x	x	x
Fatigue and Stress:	x				
heat		x			
body function		x acurracy			
effects on actions		x pass-out			
2. Combat Inside/Around Buildings					
Shell of Building:					
blocks movement	x	x	x		x
blocks LOS (Line of Sight)	x	x	x		x
Rooms and Floors:					
shape/structure	x	x			x
furniture	x	x			
Stair Wells and Elevators	--	x			
Exterior/Interior Wall Materials and Effects on Munitions/Demolitions		x to a degree			x
Rubbling:					
affects mobility	x	x to a degree			
effects on building LOS	x	x			
effects of rubbling on LOS		x			
Windows and Doors:					
pass through	x	x			x
see through	x	x			x
shoot through	x				x
reductions to LOS and firing projectiles	x	x			x
Interior Illumination/Temperature		Illum, yes.			
		Temp, no			
External Walls and Windows: firing in and out	x	x			x
Texture to External Buildings	x	x	x		

Model Capabilities	JCATS	OFP/DAR-AM	SB2	TAC-OPS	CCM
Covered Concealment Around Buildings	x	x			x
Use of UGV (Unmanned Ground Vehicle) Inside Buildings	x	unk, but probable			
3. Combined Arms/Joint Force					
Indirect Fire:				x	x
modes of employment					
high angle	x	w/a			
direct fire	x	x			
laser guided	x	no			
laser spotting	x	w/a	x		
missiles	x	x	x		
smart munitions	x				
smart mortars	x				
Aircraft:					
close air support				x	x
cannon	x	x			
bombs	x	x			
rockets	x	x			
missiles	x	x			
smart munitions	x				
forward observer	x	w/a			
laser guided	x	x rudimentary			
laser spotting	x				
helicopters			in development	x	x
cannon	x	x		x	
bombs	x				
rockets	x	x			
missiles	x	x		x	
smart munitions	x	x		x	
forward observers	x				
laser guided	x	x		x	
laser spotting	x	x			
UAVs (Unmanned Aerial Vehicle)			x	x	
flight	x		x		
sensors	x				
data stream					
munitions	x c				
interrupt LOS/line of fire trajectory	x c	x	x		x
aircraft vulnerability		x			

Model Capabilities	JCATS	OFP/DAR-AM	SB2	TAC-OPS	CCM
air defense (radar, missiles, artillery)		x			
Armor:					
capability		x	x	x	x
vulnerability		x	x	x	x
Naval Forces:		x rudimentary			ngf
		Brown water modeled well.			
munitions					
shells		x	x		
missiles		x	x		
targeting					
forward observer		x	x		x
laser guided					
laser spotting			x		
4. C4ISR					
Command and Control:					
automated and/or interactive	x c		x		
planning assistance to operator	x c		x		
Communications:	--				
voice		x			
hand signals					
radio				x	
transmission reliability					
networking					
digital or analogue					
data and/or voice					
Integration of Air/Space Intelligence Means					
Use of Sensors for Surveillance:					
air	x		x		
ground	x				
national intelligence					
IR (Infra-red)	x	x			
thermal	x		x	x	
radar	x				
sound	x				
visual	x	x	x	x	x

Model Capabilities	JCATS	OFP/DAR-AM	SB2	TAC-OPS	CCM
Integration of Joint C4ISR					
5. Rules of Engagement (ROE)					
Number of Sides:	x				
can they be made:					
friendly	x	x	x	x	x
enemy	x	x	x	x	x
neutral	x	x	x	x	x
neutral/hostile	x			x	
neutral/friendly	x				
can this be done interactively	x c		x		
Hold Fire Capability:					
no fire	x c	x	x	x	
return-fire only	x c			x	
pre-emptive	x c	x	x	x	
No-Pursuit/No-Fire Zones	-- c	x for AI	x for AI		
Limitations on Munitions/Platform Use	x c				
Conditions of Non-Lethal Use	x				
Prisoners of War (POW)	x c				
Resupply of Neutrals	x				
6. Subterranean					
Construction of Underground Structures	x c				
Movement:					
speed	x				
canalization	x				
Sensing:					
visual	x				
light	x				
sound	x				
other sensors					
Communications Effects:					

Model Capabilities	JCATS	OFP/DAR-AM	SB2	TAC-OPS	CCM
voice					
radio					
trailing land line					
Weapons/Munitions Effects:					
small arms rounds					
demolition					
grenades					
mines					
Environmental Effects:					
absorb/reflect shock from explosions					
reflect projectiles					
echo					
concussion					
collapse					
lighting					
temperature/humidity					
7. Non-Lethal and OOTW					
Incapacitate Individuals	x c	x lose mobility			
Disable Vehicles		x	x	x	
Simulate Weapons Effects:					
gas	x				
nets					
foam					
“soft” projectiles					
sponge grenades	x				
rubber bullets	x				
wooden blocks	x				
tazers					
mace/pepper spray	x				
8. Treatment of Vehicles and Aircraft					
Hulks:					
creation	x	x			
stay on screen	x	x	x		x
effect on LOS	x	x	x		x
effect on movement	x	x	x		x

Model Capabilities	JCATS	OFP/DAR-AM	SB2	TAC-OPS	CCM
Ground Movement Sensitive to:					
space between buildings	x	x	x		x
ground support (trafficability)	x	x	x		x
road width	x				
Air Movement:					
curve smoothing within 6 degrees of	x				
freedom					
landing and take-off	x	x			
helicopter movement (hover, vertical, etc.)	x	x			
Modeling of Platform:					
placement of sensors and weapons		x			
articulated parts		x			x
limitation on elevation/depression angle for		x			
weapons/sensors					
number of sensors/weapons allowed		x			x
crew modeled	x	x			
9. Terrain					
Dynamic Terrain	x c				
Terrain Resolution	x	x	x		x
Buildings	x c	x	x		x
Subterranean Features	x				
Cultural Features	x	x	x		x
Vegetation	x c	x	x	x	x
10. Technical Considerations		n/a	n/a	n/a	n/a
Programming Language	x c				
Object Oriented	x				
Computers Employed:					
type		w	w	w	w

Model Capabilities	JCATS	OFP/DAR-AM	SB2	TAC-OPS	CCM
number					
DIS/HLA Compliant	x c	x	x (in dev.)		
Interactive vs. Closed		x	x	turn-based	x
Immersiveness		x	x		
Realtime or Faster or Slower	x	x	x	x	rt
Data Retrieval/Data Tools	x	limited	x	x	x
Input/Control of Variables/Over-Ride	x	w editor		x	
Built for Training or Analysis	x	training	training	training	training
Ease of Expansion/Modification	x c	x SDK released	mission/map editor		